

# The Llobregat River Basin: A Paradigm of Impaired Rivers Under Climate Change Threats

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**Abstract** The Llobregat River represents a paradigmatic example of an impaired river subject to emerging global change impacts. This chapter provides an introduction to the main geomorphological, geological, climatic, and biological features of the river basin, as well as an overview on the hydrological alterations and the intense management of water resources in the basin. The Llobregat hydrology has experienced a significant runoff reduction during the last decades. This decrease is related to climatic drift but also to the increasing forest land cover that has promoted a 25% reduction of the streamflow. The chapter also describes the human uses of the Llobregat River waters from a historical perspective, with particular emphasis on the difficulties that an intrinsically unpredictable river like Llobregat posed to the different human uses along history. The historical development makes emphasis on the industrial activities affecting water resources during the twentieth century. The chapter includes a detailed analysis of the present situation on water extractions, discharges, and diversions that define the Llobregat River Basin as a deeply impaired ecosystem, especially in the most downstream reaches.

**Keywords** Climate, Geology, History, Land use change, Water diversions, Water flow trend, Water treatment

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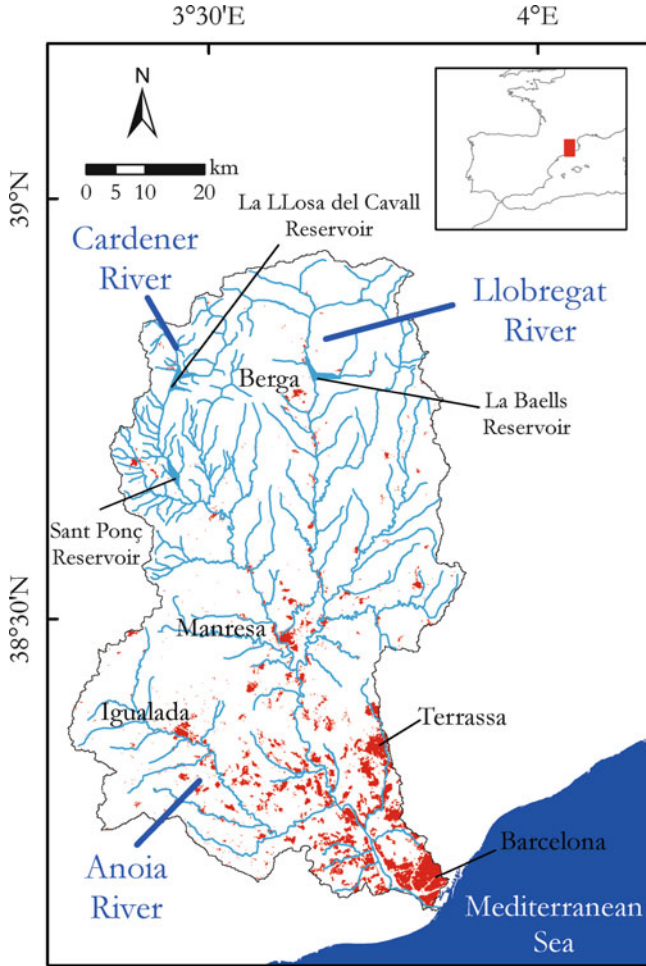
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## 1 The Llobregat River Basin

The Llobregat River is located in NE Spain, running for 165 km to drain an area of 4,948 km<sup>2</sup> (Fig. 1). Long-term mean discharge at the mouth is 603 hm<sup>3</sup> year<sup>-1</sup> or 19 m<sup>3</sup> s<sup>-1</sup>. It has two main tributaries, the Cardener and Anoia Rivers (Fig. 1). The headwaters of the Llobregat and Cardener Rivers lie in the rather pristine Eastern Pyrenees, but soon downstream they are already impacted by sewage treatment plants and industrial effluents (estimated at 137 hm<sup>3</sup> year<sup>-1</sup> or 4.3 m<sup>3</sup> s<sup>-1</sup>), as well as by potash-mining activities in the Cardener reaches just upstream Manresa. The lower course flows through one of the most densely populated areas of the Mediterranean region (Barcelona Metropolitan Area, over 3 million people), and the waters receive large inputs from industry and urban origin. The case of the Anoia River is somehow different: its headwaters lie in an agricultural area, downstream it flows through an industrialized zone (paper mills, tannery, and textile industries), and near the confluence with the Llobregat River the main land use is vineyard fields (Fig. 2).

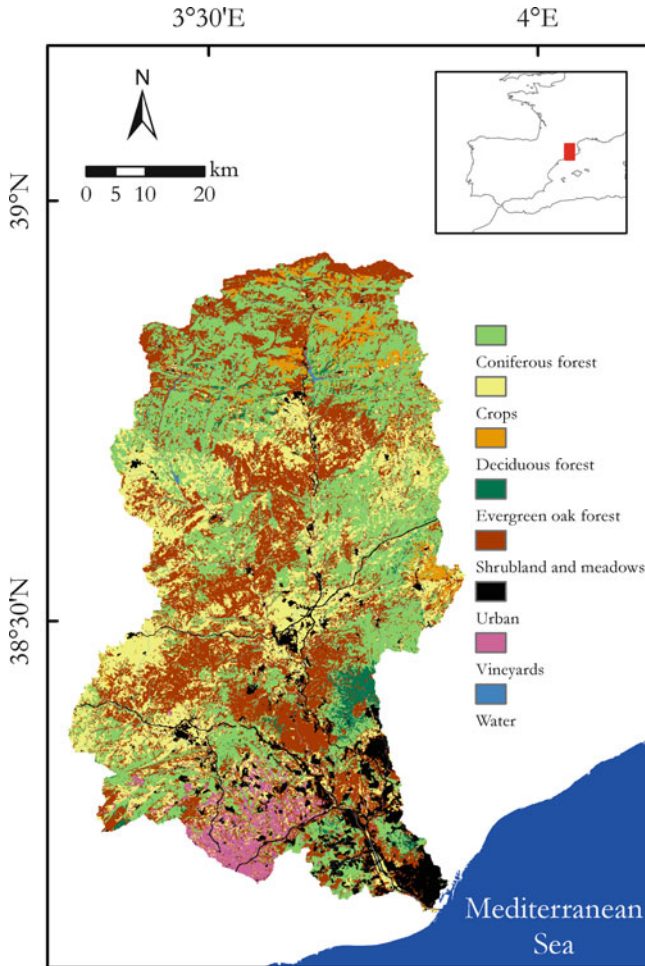
Water resources from the Llobregat basin are fundamental for the water supply scheme of the Barcelona Metropolitan Area. In fact, due to the intrinsic variability of the Mediterranean climate, three large dams were built in upstream sections of the Cardener and Llobregat Rivers to ensure water supply during low flow periods (Fig. 1). Presently as much as 30% of the long-term mean annual flow is eventually diverted for human uses, with intakes concentrated in the downstream section of the basin. Aquifer withdrawals are also numerous in the deltaic region and play an important role when water quality or quantity of the Llobregat River is insufficient. A new seawater desalination plant with a capacity of 60 hm<sup>3</sup> year<sup>-1</sup> started operation recently to help overcoming the threats posed by abnormal, high-frequency water scarcity episodes during the last decade.

Due to the ever increasing human pressure by the end of the 1980s the Llobregat River was one of the most polluted and degraded in Western Europe, and the



**Fig. 1** The Llobregat basin with indication of the main rivercourse and its tributaries, and the location of the three large reservoirs. Urban settlements are also depicted as red areas; only the largest ones are named

overexploitation of the underground water led to salinization of the deltaic aquifer, rendering 30% unusable. Since then, wastewater treatment plants with tertiary facilities have been built along the basin, and the situation has improved dramatically. Nowadays, infrastructures prevent excessive pollution of the river by intercepting specific effluents, such as the channels receiving treated urban wastewater from the Riera de Rubí (near Terrassa) and those collecting brine from the salt-mining sites. Apart from these, there is a major irrigation channel on the right side of the river, the Canal de la Dreta, which provides water for horticulture in the Delta. On the left side of the downstream reaches, the Canal de la Infanta was also built for irrigation purposes, but now its main role is to prevent wastewater from



**Fig. 2** Land uses distribution in the Llobregat basin. Based on the information gathered by the Thematic Mapper sensor of the Landsat satellite during the year 2002 (30 m grid resolution). Source: Institut Cartogràfic de Catalunya (ICC)

industries and towns reaching the river upstream from main water supply intakes. See Sect. 3 for a comprehensive description of those infrastructures.

The delta of the Llobregat River lies to the south of Barcelona and covers about 100 km<sup>2</sup> and constitutes a valuable natural habitat close to a big metropolitan area. Its wetlands are part of the RAMSAR network and play a critical role in the wintering of many migratory birds. The delta aquifer is an important freshwater resource for the metropolitan region, with a groundwater capacity around 100 hm<sup>3</sup>, used by numerous industries, agriculture, and cities. The fertile delta farmland supports intensive agriculture supplying the local market. Since the 1960s, the delta's land has been under constant pressure from Barcelona's urban and industrial

expansion. Most important logistics and transportation facilities in the region (port, airport, motorway network, and railways) were built in this area taking advantage of the flat landscape. The recent port extension even forced a southward movement of the river mouth. Less than 5% of the original wetlands in the area now remain, and in some municipalities half of agricultural land has been lost in the last decade [1].

## 1.1 Geology

The Llobregat watershed is the product of tectonic movements during the late Mesozoic over 29 million years ago. Upon the rupture of Pangea, the geological plate carrying Iberia drifted separately from Eurasia and Gondwana—prehistoric Africa and South America. The rotation of Gondwana then pushed the Iberian plate against Eurasia causing a collision that raised the Pyrenees Mountains and erected the first contours of the Llobregat watershed. The convergence of the Iberian and Eurasian plates culminated during the Quaternary period over 2 million years ago [2]. The collision of Iberia with Eurasia initially created a bay, and then a salt water lake. Over time the water evaporated, leaving behind layers of salt and other minerals that were pushed up into the Pyrenees Mountains as the two geological plates converged.

The Llobregat River crosses several present geological units (Fig. 3). Headwaters are situated in the Eastern Pyrenees, in an area composed of Upper Paleozoic to Cenozoic sedimentary (mainly limestones and sandstones) and volcanic rocks [3]. In its central part the Llobregat River flows through a Cenozoic Basin composed of a regressive (marine to continental) Eocene-Paleocene age sedimentary sequence. The transition evaporites (gypsumanhydrite, halite, and potash facies) have an Upper Eocene age [3] and there has been salt-mining activity since Neolithic times in the area. Close to the Mediterranean Sea, the Llobregat River crosscuts the Catalanian Coastal Ranges, made up of Hercynian basement and Mesozoic to Cenozoic cover. The Hercynian basement consists of Paleozoic metasedimentary rocks and late Hercynian granites, upon which the Mesozoic sedimentary sequences have been deposited. The delta, consisting of Quaternary sediments, is composed of conglomerates, sands, and marine marls.

Previous work in this area [3] has shown that the chemistry of most of the stream waters in the Llobregat basin is mainly controlled by the weathering of the Tertiary sediments, mainly limestone and marls deposited in upstream regions and middle reaches (Fig. 3). Despite its small extent, the salt deposits have a dramatic effect in the lower Cardener and Llobregat, enhanced by the mining activities. The signature of water is derived from weathering of limestone and marls ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{Sr}^{2+}$ , and  $\text{Ba}^{2+}$ ), gypsum ( $\text{Ca}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Sr}^{2+}$ , and  $\text{Ba}^{2+}$ ), and halite and sylvite ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ , and  $\text{SO}_4^{2-}$ ).



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